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Timber Harvest and the
Ecological Sucession of
Bear Foods in the Greater
Yellowstone Area.

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"Timber Harvest and the Ecological Succession
of Bear Foods in the Greater Yellowstone
Area."

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GRIZZLY BEAR FOOD PRODUCTION IN RESPONSE TO TIMBER
MANAGEMENT IN THE YELLOWSTONE ECOSYSTEM

FINAL REPORT

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by

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TABLE OF CONTENTS

	Page
ABSTRACT.....	viii
INTRODUCTION.....	1
STUDY AREA.....	5
METHODS.....	11
Vegetation Sampling.....	11
Energy Production Estimates.....	16
Sound Level Measurements.....	17
Bear Sign Transects.....	18
Data Analyses.....	19
RESULTS.....	22
Stand Comparisons.....	22
Food Production.....	24
Berry Production.....	33
Energy Production.....	35
Frequency.....	35
Phenology.....	39
Sound Levels.....	41
Bear Sign.....	41
DISCUSSION.....	44
Food Production.....	44
Energy Production.....	48
Sound Levels.....	50
Bear Use.....	51
MANAGEMENT IMPLICATIONS.....	53
LITERATURE CITED.....	58
APPENDICES.....	64
A. Description of Variables and Species List.....	65
B. Tabulated Results.....	69
C. Statistical Models.....	72

LIST OF TABLES

Table	Page
1. Means of observed variables measured at the transect level.....	23
2. Average canopy coverage of selected grizzly bear foods by age class.....	31
3. Estimated gross energy produced per hectare by vegetative life form for individual age classes.....	38
4. Estimated digestible energy produced per hectare by vegetative life form for individual age classes.....	38
5. Plot and transect variables measured in data collection.....	66
6. Species list of selected grizzly bear foods.....	68
7. Correlation coefficients for wet and dry weights determined from clipped plots.....	70
8. Mean wet and dry weights in kilograms per hectare for vegetative life forms.....	71
9. Statistical models.....	73

LIST OF FIGURES

Figure	Page
1. Maps of Study Area.....	6
2. Map of Precipitation Isohyets.....	9
3. Graph of Life Form Canopy Coverage.....	25
4. Graph of Graminoid Production.....	27
5. Graph of Forb Production.....	28
6. Graph of Grouse Whortleberry Production.....	29
7. Graph of Globe Huckleberry Production.....	32
8. Graph of Globe Huckleberry Production by Scarification Method.....	34
9. Graph of Berry Production in Numbers of Berries..	36
10. Graph of Berry Production in Weight of Berries...	37
11. Graph of Bear Food Frequency.....	40
12. Graph of Bear Use by Type of Activity.....	43
13. Graph of Bear Sign by Type of Area.....	43

ABSTRACT

The production of common grizzly bear (Ursus arctos) foods on clearcuts as compared to uncut stands within the subalpine fir (Abies lasiocarpa) habitat type in the western and northwestern Yellowstone ecosystem was investigated during 1993. Wet and dry plant weights were estimated and correlated to clipped weights for three age classes of clearcuts as well as uncut stands. Clearcut stands 0-10 years old, 11-20 years old, and ≥ 21 years old produced larger weights of graminoids and lower weights of shrubs on average than uncut stands. Forb production was variable. Uncut stands produced larger numbers and weights of grouse whortleberry (Vaccinium scoparium) and globe huckleberry (V. globulare) berries than clearcuts. Converting bear food production to energy production revealed that younger clearcuts produce the most gross and digestible energy, which declined with clearcut age. This energy is attributed primarily to graminoids, which is considered to be a low quality forage for grizzly bears. Uncut stand gross and digestible energy production was intermediate between the 11-20 and \geq clearcut age classes. Forbs, grouse whortleberry berries, and globe huckleberry berries were important in the estimated energy production for uncut stands. Frequency of occurrence of plant life forms varied with successional stage. Graminoid and forb frequencies of occurrence were highest in recent clearcuts and declined with successional stage. Shrub frequency increased with successional stage. Sound measurements indicate that sounds travel farther in clearcuts < 20 years of age than in older clearcuts and uncut stands. Bear sign determined from incidental and transect observations was more prevalent in uncut stands than in clearcuts.

INTRODUCTION

Vegetative response to clearcutting has been documented in numerous studies (Dyrness 1973, Schmidt 1979). Many studies have also related clearcutting to wildlife forage production and use. Forage production for elk and deer has generally been increased by tree canopy removal associated with clearcutting, but use of clearcuts is influenced by cover within and around the clearcut, climatic conditions, season and level of human disturbance (Lyon 1979, Lyon and Basile 1979, Lyon and Jensen 1980, Wallmo and Schoen 1980).

Studies of black bears (Ursus americanus) in the Pacific Northwest indicate that the availability of foods increases with clearcutting and that black bear populations respond favorably to this increase (Lindzey et al. 1986). Lindzey and Meslow (1977), Schmidt (1979), Bratkovich (1985), Hamer and Herrero (1986), and Noyce and Coy (1989) have also shown an increase in black bear and grizzly bear (Ursus arctos) foods following clearcutting. Studies in northwestern Montana indicate a similar trend (Martin 1983, Zager et al. 1983). However, some debate exists over the applicability of these studies to the Yellowstone ecosystem, which is drier and has greater temperature extremes than the Northern Continental Divide Ecosystem (NCDE) (Mattson and Knight 1991).

Some debate also exists over the use of clearcuts by bears. Unsworth (1984) found that black bears avoided

clearcuts in west-central Idaho. Lindzey and Meslow (1977) reported black bear use was less than expected in clearcuts in southwestern Washington. Zager (1980) and Waller (1992) found that grizzly bears tend to avoid clearcuts. Most studies indicate that an increase in human activity associated with logging contributes to this avoidance (Mace and Jonkel 1980, Archibald et al. 1987, McLellan and Shackleton 1988). Thus, current information suggests that although clearcuts may provide increased forage, actual use may be diminished by increased human disturbance.

Within the NCDE, globe huckleberry (Vaccinium globulare) fruit comprises a major food source for the grizzly bear during the summer and fall when berries ripen (Martin 1983, Mace and Jonkel 1986). Food habit studies in the Yellowstone ecosystem indicate huckleberries are used to a lesser degree (Mealey 1975, Blanchard 1978, Mattson et al. 1991), primarily due to lack of availability. Climatic conditions within the Yellowstone ecosystem may preclude huckleberry plant establishment and dispersal as well as berry production. Although the majority of reproduction of huckleberry plants occurs through rhizomes (Stark 1987), damage due to temperature fluctuations may occur on existing as well as sprouting plants. Minore and Smart (1978) found that temperatures ≤ -6 C damaged young seedlings. Plant damage also occurs when the tops remain above snowpack (Stark 1987). Berry production can be diminished by frost

during flowering. Berry initiation and loss of pollination may also be reduced due to cool rainy springs or summer drought conditions (Stark 1987). During periods of intense sunlight and warm temperatures, shade can be important in reducing sun damage to plant foliage (Smith 1962).

The effects of climate can be compounded on areas in which the canopy cover has been removed. Hungerford (1979) reported higher net radiation levels and greater temperature fluctuations in clearcuts when compared against uncut stands. Clearcutting also resulted in a decrease in the number of frost-free days when compared to uncut areas. These factors could limit the ability of globe huckleberry to survive and reestablish in clearcuts.

The purpose of this study is to determine the effects of clearcutting in the Yellowstone ecosystem on forage commonly utilized by grizzly bears and to measure some of the variables which may affect grizzly bear use of clearcuts. This was done by comparing clearcuts to uncut forest. The primary objectives were to compare the effects of clearcutting on grizzly bear food production, determine if bear foods intrude into clearcuts from surrounding uncut areas, document phenological differences between clearcut and uncut stands, measure effects of tree canopy removal on sound transmission, and estimate bear use of cut and uncut stands. Three hypotheses were tested: (1) grizzly bear food production in clearcuts does not differ from that in uncut

forest, (2) grizzly bear food production near the edge of clearcuts does not differ from that in clearcut interiors, and (3) levels of sound transmission within clearcuts and uncut forest do not differ.

STUDY AREA

The study area encompassed approximately 1,035 km² of the western and northwestern Yellowstone Ecosystem. Yellowstone National Park served as the eastern border. The area was bounded by the Lee Metcalf Wilderness Area, MT, to the north, the Madison-Gallatin county line, MT, to the west, Warm River, ID, to the southwest, and Robinson Creek, ID, to the south. The study area was subdivided into two sections, the Montana section and the Idaho section. Hebgen Lake Ranger District of the Gallatin National Forest contained the entire Montana portion of the study area with the southern boundary being the Montana-Idaho border. The Idaho area consisted of the plateau region within the Ashton and Island Park Ranger Districts of the Targhee National Forest (Figures 1a and 1b).

The study area was managed for multiple use by the U.S.D.A. Forest Service with timber harvest being a primary use, but recreation was also important. Nineteen percent of the total area within the Montana portion had been logged by 1993. Within the Idaho portion of the study area approximately 24% and 53% of the total area and harvestable area, respectively, were cut from 1981 to 1993. The majority of timber harvest occurred during this period but a few older clearcuts existed. However, the acreage affected by older cuts was small as compared to that cut from 1981 to 1993.

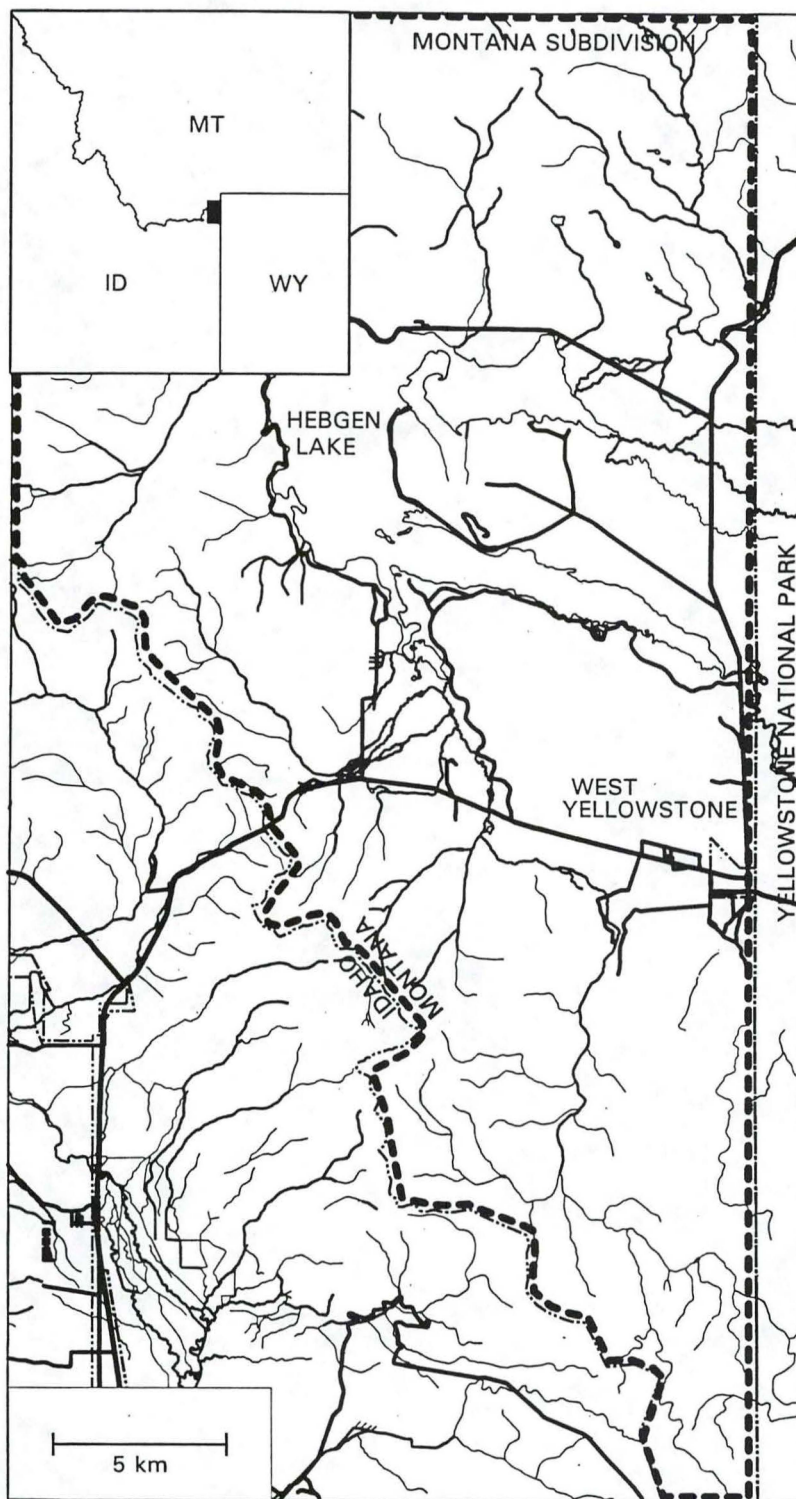


Figure 1. (a) Northern half of study area, northwestern Yellowstone ecosystem, Montana and Idaho

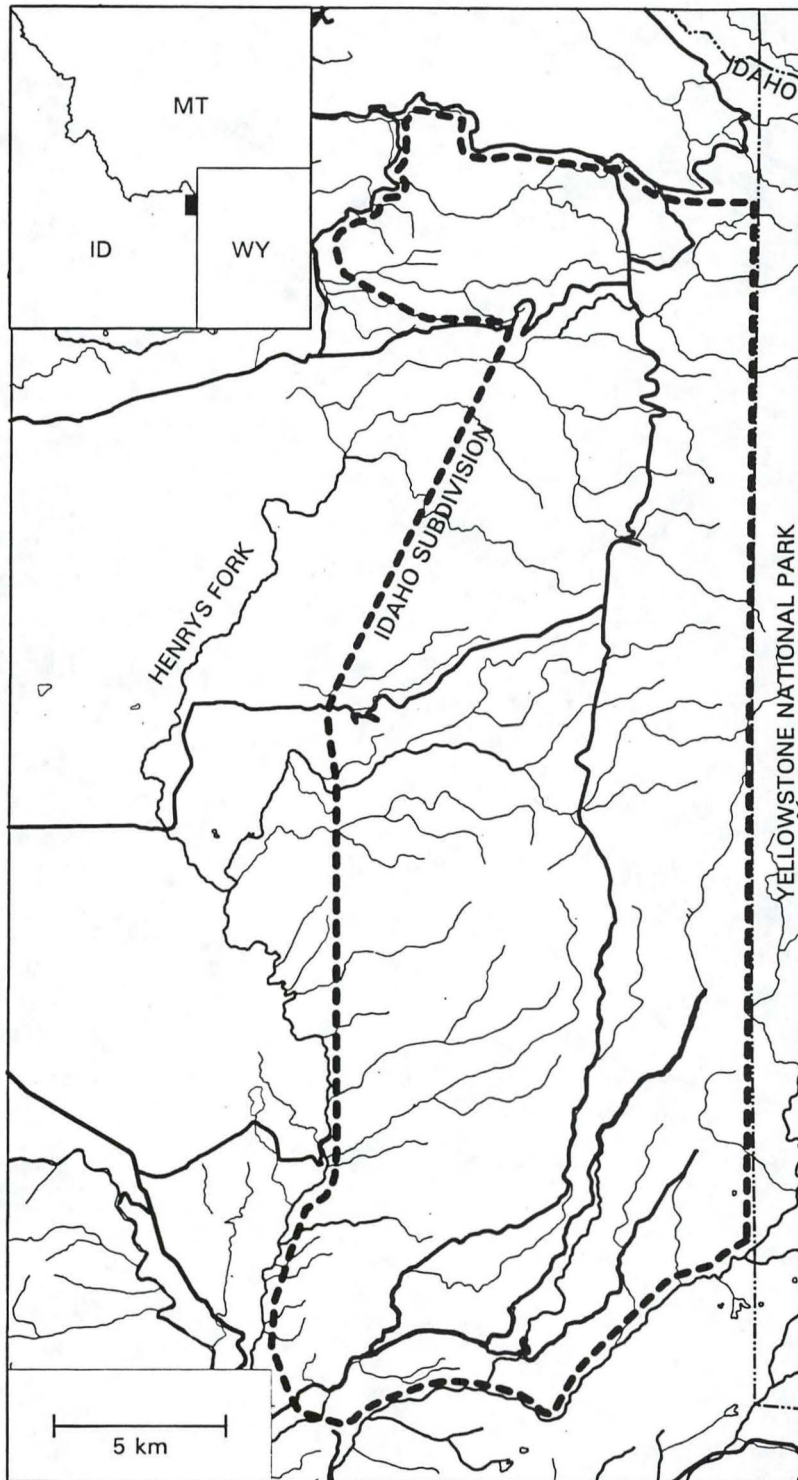


Figure 1. (b) Southern half of study area, western Yellowstone ecosystem, Idaho.

The soils within both portions of the study area were primarily cryochrepts and cryoboralfs (Davis and Shovic, 1984). Topography ranged from gently sloping to rugged mountain topography. Elevations varied from 1,707 m along the lower portions of the plateau to approximately 3,048 m along the Continental Divide. Mean precipitation levels ranged from 76 cm to 152 cm increasing along elevation gradients (Farnes 1993 pers. commun.) (Figure 2). Snow provided the majority of precipitation which fell on the area. At Hebgen Dam, located near the center of the Montana portion of the study area at an elevation of 1,996 m, yearly precipitation from 1961-1990 averaged 76.7 cm. Temperature extremes ranged from -17 C for January to 26 C for July. During 1993 yearly precipitation totaled 67.5 cm, approximately 9 cm below average. However, the spring and summer of 1993 were wet and cool with precipitation rates approximately 8.3 cm above normal for the period of April through August. Several instances of frost occurred in the spring (NOAA, 1993).

Vegetation types within the study area varied from closed canopy coniferous forests to alpine flora at higher elevations. Lodgepole pine (Pinus contorta), Douglas fir (Pseudotsuga menziesii), and subalpine fir (Abies lasiocarpa) were dominant in the overstory, with whitebark pine (Pinus albicaulis) and Englemann spruce (Picea engelmannii) present as minor components.

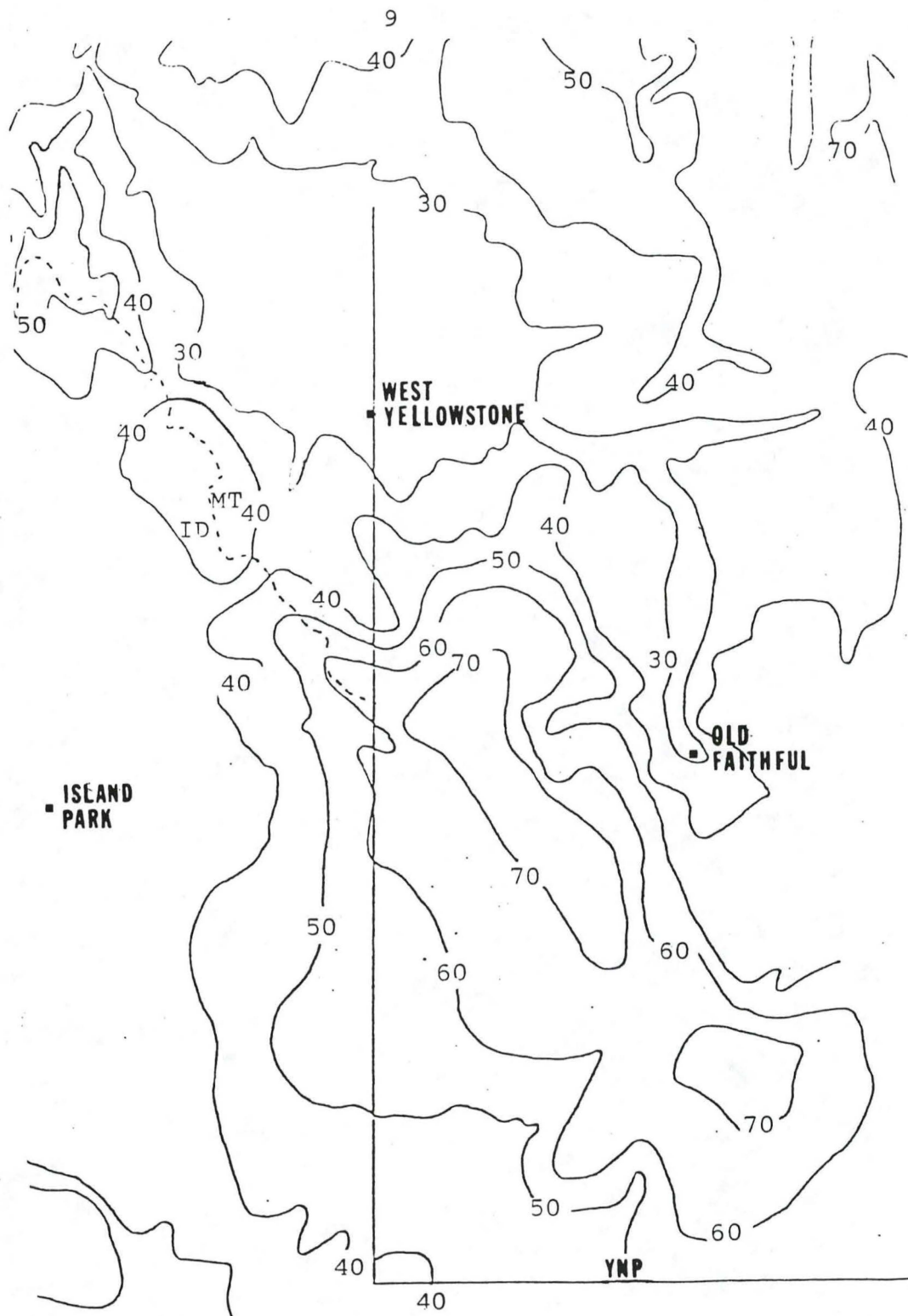


Figure 2. Precipitation isohyets of the Ashton - West Yellowstone - Old Faithful area, 1961 - 90 base period. Precipitation is in inches. Compiled for this study by P. Farnes.

Pfister et al. (1977) and Steele (1981) further describe the spruce/fir habitat types of southwestern Montana and southeastern Idaho, respectively.

METHODS

Production of grizzly bear foods on clearcuts and uncut stands was determined by estimating canopy cover and plant wet and dry weights. Thirty-five clearcuts within the subalpine fir/globe huckleberry habitat type were sampled during the spring, summer and fall of 1993. Clearcuts ranged in age from 1 to 25 years and in size from 2 to 58 ha. Control plot sizes were consistent with clearcut sizes and primarily fell within the mature to over-mature successional stage (Despain 1973). Fifty stands were sampled resulting in 327 transects. Bear food weights were estimated and plants occasionally clipped in 3270 microplots (0.5 m² frames). Clipping provided a correlation coefficient between estimated and actual weights of selected bear food life forms (Appendix B, Table 7).

Vegetation Sampling

In order to reduce variation between plots, sampling was restricted to the subalpine fir/globe huckleberry habitat type. This habitat type was chosen due to its plant species diversity (Pfister et al. 1977), a high mean diversity of bear feeding activity in climax or near climax successional stages (Mattson and Knight 1987), relative importance of berries as a food source for bears, and the abundance of sampling sites.

Clearcut and untreated study sites were determined from U.S.D.A. Forest Service maps, aerial photos, and direct

observation. The acreage and ages of the clearcuts were determined from Forest Service records where possible. Clearcuts were placed into one of three age classes based on the year in which the last scarification occurred. Recent clearcuts (≤ 10 years old) were scarified between 1982 and 1991, mid-aged clearcuts (11 - 20 years old) between 1972 and 1981, and old clearcuts (≥ 21 years old) prior to 1972. One control site, consisting of uncut forest, was chosen for a clearcut or group of clearcuts within the same general location, and of similar aspect. Fifteen, twelve, eight, and fifteen stands were sampled in the 0-10, 11-20, 21+, and control age classes, respectively.

Inadequate or nonexistent information made it difficult to determine actual ages of the pre-1981 clearcuts in the Idaho portion of the study area. Therefore, the ages of the majority of clearcuts harvested prior to 1981 were determined by counting branch rings of trees present within each clearcut. Although the number of tree rings produced is usually one per year, at times two may occur depending on environmental conditions. However, I believe that branch ring counts provided an adequate estimation of age and was within the precision needed. No clearcuts cut prior to 1972 were found within the subalpine fir/globe huckleberry habitat type in the Idaho portion of the study area.

Distance to roads, streams, and meadows from the center of each clearcut was recorded. Slope, slope shape, aspect,

cover types, harvest type, and scarification type were noted for each study site and compared to determine any differences between clearcut age classes and control sites.

Individual clearcuts were divided into two areas, the periphery and interior. I assumed that the majority of encroachment of plants into the periphery of clearcut areas would occur within 30 m of the clearcut edge. Therefore, the periphery was defined as a strip 30-m wide which extended along the outside edge of the clearcut. The interior consisted of the remaining area.

Study plots were sampled using a stratified sampling scheme, modified from methods described by Oosting (1956). Transects were located within each plot and the wet and dry weights of current years growth of grizzly bear foods estimated. The interior and periphery of each clearcut plot were divided into three or four sections based on the stand's shape and size. A left and right side were designated for each clearcut by standing at the edge of the clearcut, which was lowest in elevation and facing up slope. Interior sections to the left side of the clearcut were sampled first. This was done by establishing a transect within that section using a "random distance and direction" method from the center of the section. Transects in additional sections were located by pacing a random distance from the initial transect in a direction perpendicular to the predominant aspect of the clearcut. Only distances that

ensured that each additional transect fell within a distinct section were used. This resulted in one transect in each section.

The initial peripheral transect was located by following a random direction from the center of the clearcut to its edge. Subsequent periphery transects were located in the remaining sections by pacing random distances along the edge of the clearcut, again resulting in one transect per section. Only periphery areas with edges consisting of uncut forest were sampled. Control plot transects were established in a manner similar to interior clearcut plots. Transects were run parallel to the predominant aspect of the study plot except in the periphery area where they were directed towards the center of the clearcut.

Transects measured 30.48 m in length. A belt transect 1-m wide was run along the length of each transect; the number of trees, logs, stumps, ant hills, and gopher mounds were counted. All items were counted when at least one-half of that individual item fell within the belt transect. In addition, the crown cover of Vaccinium spp. was determined by recording the amount of crown intercept directly under the transect line. The variables measured at the plot and transect level are described further in Appendix A, Table 5.

For each transect, weights for current years growth of grizzly bear foods were estimated within ten individual 0.5 m² frames (microplots) located every 3.05 m along the

transect. Wet weight estimates were classified on a scale from one to six based on the following grouping system:

(1) 0.0-9.9 g, (2) 10.0-19.9 g, (3) 20.0-29.9 g, (4) 30.0-39.9 g, (5) 40.0-49.9 g, and (6) 50.0+ g. Clipping was done occasionally to determine a correlation between estimated and actual wet and dry plant weights following the combination doubling sampling technique described by Carande and Jameson (1986).

When the transects in each section were completed, an adequacy of sample test was performed in order to determine if additional transects were needed. If additional transects were needed, their locations were determined by a random-distance and direction or random-direction method from the center of the clearcut for interior and periphery areas, respectively. This was done until an adequate sample was achieved. The formula used for determining adequacy of sample was: $n = (st/xl)^2$ where n is sample size, s is standard deviation of the sample already collected for that individual site, t is the t value at the 0.05 level (in this case, 1.96), x is the mean of the sample, and l is the percentage used to establish a confidence interval based on the mean in which the 95% confidence interval should not exceed (10% will be used) (Huntsberger and Billingsley 1987). Previously collected data indicated an exponential distribution of shrub weights. Therefore standard deviations and means were calculated using a square roots

transformation of assigned weight classification (Box et al., 1978). The bear foods used for estimation were selected based on the findings of Mattson et al. (1991) and are listed in Appendix A, Table 5.

Energy Production Estimates

Dry plant and berry weights were converted to gross energy and apparent digestible energy available to bears based on the work of Mealey (1975), Bunnell and Hamilton (1983), and Pritchard and Robbins (1990). In these studies gross energy rates and apparent digestion rates of selected bear foods were estimated. Mealey (1975) determined energy ratings for observed bear foods by submitting plants found in bear scat to chemical analysis and comparing that to plants collected within his study area. Bunnell and Hamilton (1983) and Pritchard and Robbins (1990) determined gross and digestible energy rates in a similar way, except captive grizzly bears, black bears, and dogs were fed the foods. Graminoid energy ratings were determined for this study using a 3.3 kcal/g and a 19.4% apparent digestibility as determined by Mealey (1975). Forb energy rates were calculated using the lowest reported values for a forb by Mealey (1975). The forb used was Equisetum arvense which was shown to have a gross energy rating of 2.9 kcal/g and 12.8% digestibility rating. Grouse whortleberry had a 4.0 kcal/g gross energy rating (Mealey 1975) and V. corymbosum was determined to have an apparent digestibility of 62.7%

(Pritchard and Robbins 1989). These values were used for energy estimates of both grouse whortleberry and globe huckleberry berries. Energy levels were extrapolated to kcal/ha for each age class of clearcut by plant life form using the indicated values. All grouse whortleberry and globe huckleberry berries generally did not become ripe at the same time. Therefore, an average ripe berry weight was determined for each Vaccinium species. Wet weights of unripe berries were then estimated using this average. Dry weights for berries were determined by weighing a sample of berries obtained during the middle of August and oven drying them until moisture content was removed. The berries were then weighed and a ratio of wet to dry weight was then determined. All dry berry weights for grouse whortleberry and globe huckleberry were converted into dry weights using this ratio. Energy levels based on berry production were then estimated using the projected dry weights.

Sound Level Measurements

Sound transmission characteristics of a habitat affect grizzly bear use of and displacement from that habitat. To determine the effects of tree canopy removal on sound transmission, sound levels within clearcut and uncut stands were recorded using a sound meter set to detect frequencies ranging from 32 to 10,000 Hz. Clearcuts were sampled based on the 10 year age classes proposed earlier. Control plots were located in similar areas to the clearcuts. An idling

truck was used to produce sound, which was measured at one meter from the truck and every ten meters perpendicular to the truck until the noise level fell below the lower limit of the meter (50 Db). Each clearcut and control was sampled at three points along a logging road. The points within clearcuts were located by traveling approximately one-third of the distance in from where the road bisected the two most distant edges of the clearcut and at the midpoint.

Distances between measurements in control plots were determined by estimating the average distance traveled between observation points within the representative clearcuts. Only those sites with fairly even slopes were sampled in order to reduce variation due to changes in topography. Sampling only occurred in the fall and on days when noise caused by the wind did not register on the meter.

Bear Sign Transects

Areas in which a diversity of clearcut age classes was present were searched for evidence of bear use. This was accomplished by the use of transects. Areas to be searched were divided into two aspect categories, the first ranging in direction from northwest through east and the second ranging from southeast through west. These two aspect categories were chosen based on the assumption that vegetation within each category would be the most similar, particularly for globe huckleberry (Pfister et al. 1977). One clearcut in each of the age classes present and of

similar aspect category was sampled. A single transect was used for each clearcut. One control transect was established for each clearcut or group of clearcuts within the same general area and of similar aspect category. Each transect was approximately 1-km long and spanned elevation gradients within the study site (Reinhart and Mattson 1992). Where possible, the transects followed game trails. Otherwise, they were located randomly. Observed bear sign, such as disturbed logs, digging sites, scats, tree markings, daybeds, sightings or any other disturbance that could be contributed to bears was recorded. Bear species was also recorded where determination was possible. All disturbed logs within direct view of the first observation were considered to be a single feeding site by one bear. These sites were recorded as a multiple log use site, consequently only one data point was assigned. A general site description including habitat type, tree, shrub, forb, and grass canopy cover, basal area, dominant species, slope, aspect, elevation, and distance to roads and nearest clearcut edge was documented for each bear activity site. All incidental observations of bear activity were also recorded. These were then pooled with the observations made on transects.

Data Analyses

All data were entered into a database and analyzed using Program SAS (SAS Inst. 1990). Grizzly bear foods were

grouped into life form categories for statistical analysis. These categories consisted of graminoids, forbs, grouse whortleberry, and globe huckleberry. Grouse whortleberry and globe huckleberry berry numbers and weights were considered as distinct groups. Bear-food weights, canopy cover, log and stump numbers, gopher mounds, and basal area were transformed using a square root conversion (Box et al. 1978). Transformation resulted in a normal distribution. Data measured at the microplot level were analyzed using an analysis of variance with three-stage nesting in which transects were nested within location (ie interior or periphery), location was nested within an individual stand and each stand was nested within an age class. The measurements collected at the microplot level included canopy cover and wet and dry bear food weights, with the exception of berries. Berry numbers and weights were non-normally distributed, therefore, the nonparametric Kruskal-Wallis One-way Analysis of Variance by Ranks test was used (SAS Inst. 1990). These two statistical methods were used to test the hypothesis of no difference in food production among clearcut age classes and between clearcut age classes and uncut stands.

Data collected at the transect level consisted of the number of logs, stumps, and gopher mounds as well as basal area, slope, aspect, and tree canopy cover. These were generally considered stand description variables, even

though logs, stumps, and gopher mounds could be considered a source of bear food. Analysis of variance with two-stage nesting was used to test the hypothesis of no difference among clearcut age classes or between clearcut age classes and uncut stands for these variables. The two-stage nesting consisted of location nested within a stand and each stand nested within an age class.

Testing of the hypothesis of no difference in globe huckleberry production between interior and periphery sites was done using a factorial design for each individual age class (Box et al. 1978).

Sound level measurements were analyzed using a one-stage nested design where the measurement location was nested within the age class. This method was used to test the hypothesis of no difference among clearcut age classes or between clearcuts age classes and uncut stands. Models used in statistical analysis are presented in Appendix C.

Dunnett's test for comparison against a control (DTAC) and Tukey's Studentized Range Test (TSR) were used to make comparisons of clearcut age classes against the control and comparisons among clearcut age classes, respectively (SAS Inst 1990).

RESULTS

Stand Comparisons

Elevation ($P = 0.92$), slope ($P = 0.98$), slope shape ($P = 0.90$), or aspect ($P = 0.76$) did not differ significantly among clearcut age classes or between clearcuts and the controls. The number of trees, by size, varied with age class. Seedling counts did not differ significantly among clearcuts or between clearcuts and controls ($P = 0.14$). Saplings and pole-size trees, however, did differ significantly ($P = 0.0001$). Dunnett's test for comparison against a control and TSR test indicated that clearcuts within both the 11-20 and 21+ age groups contained significantly more sapling-size trees than uncut stands and 0-10 year old clearcuts. Uncut stands had more sapling-size trees than the 0-10 age group ($P < 0.05$). The first two age classes did not contain pole-class trees. Hence, there were significantly less of this size of tree than in the controls. The 21+ age group also contained significantly fewer pole-size trees than the controls ($P < 0.05$). Control plots were the only sites to contain mature and large mature trees (Table 1).

Basal area and tree canopy cover differed significantly among clearcut age classes and control sites ($P = 0.0001$). Dunnett's test against a control revealed that basal area and tree canopy cover were significantly greater for control

stands than clearcuts of all age classes ($P < 0.05$)

(Table 1).

Control stands also contained more downed logs than clearcuts regardless of the age class ($P < 0.05$). The number of downed logs within clearcuts appeared to decline with age, although the differences were not statistically significant. However, stumps were more prevalent in each clearcut age class than in the controls ($P < 0.05$). Gopher mounds were also significantly more abundant in clearcuts of all age classes than in control stands ($P < 0.05$) (Table 1). Ant hills were almost nonexistent within the study sites.

Table 1. Mean of observed variables measured at the transect level for each clearcut age class and the control.

	0-10 ¹ age class 104	11-20 age class 96	21+ age class 53	CONTROL 74
Sample size				
Variable*				
Basal area (ft ²)	1 ^a	38 ^b	58 ^c	156 ^d
Tree canopy (%)	8 ^a	51 ^b	47 ^c	58 ^d
² Seedling (#/30.5 m ²)	5 ^a	10 ^a	8 ^a	5 ^a
² Sapling (#/30.5 m ²)	0 ^a	5 ^b	4 ^b	2 ^c
² Pole (#/30.5 m ²)	0 ^a	0 ^a	0 ^a	2 ^b
² Mature (#/30.5 m ²)	0 ^a	0 ^a	0 ^a	1 ^b
² Large mat. (#/30.5 m ²)	0 ^a	0 ^a	0 ^a	1 ^b
Log (#/30.5 m ²)	6 ^a	5 ^a	4 ^a	11 ^b
Stump (#/30.5 m ²)	2 ^a	1 ^a	1 ^a	<1 ^b
Gopher mounds (#/30.5 m ²)	3 ^a	2 ^a	2 ^a	1 ^b

1 Age classes based on number of years in which scarification took place prior to 1991.

2 Size class measurements (dbh) derived from USFS Ecosystem Handbook FSH 12/87 R-1 Suppl.

* Different letters indicate significant difference in age class at the $P \leq 0.5$ level for individual variables.

Canopy coverage for all species, including non-bear foods within the graminoid, forb, and shrub vegetative life forms were recorded and averaged for each age class. Graminoid canopy cover was greatest (17%) in 0-10 year age class and declined as age increased. Forb canopy cover also declined with increase in age ranging from 14% in the 0-10 and 11-20 age classes to 10% for the control. Shrub canopy cover generally increased with clearcut age being lowest (10%) in the 0-10 age class and highest (30%) in uncut stands (Figure 3).

Food Production

Average grizzly bear food production between the periphery and interior of clearcuts did not differ significantly regardless of vegetative life form for all age classes ($P > 0.05$). However, globe huckleberry plants within the 0-10 age class averaged 124 ± 8 kg/ha in the periphery and 82 ± 6 kg/ha in the interior for wet weights. Dry weights ranged from 54 ± 4 kg/ha to 38 ± 3 kg/ha for the periphery and interior, respectively. This difference was nearly significant for both wet ($P = 0.059$) and dry ($P = 0.053$) weights.

Graminoid production differed significantly among clearcut age classes as well as between clearcut age classes and uncut stands for wet ($P = 0.0003$) and dry weights ($P = 0.0012$). Mean graminoid production ranged from 550 ± 15 kg/ha to 294 ± 11 kg/ha wet weight and 190 ± 6 kg/ha to

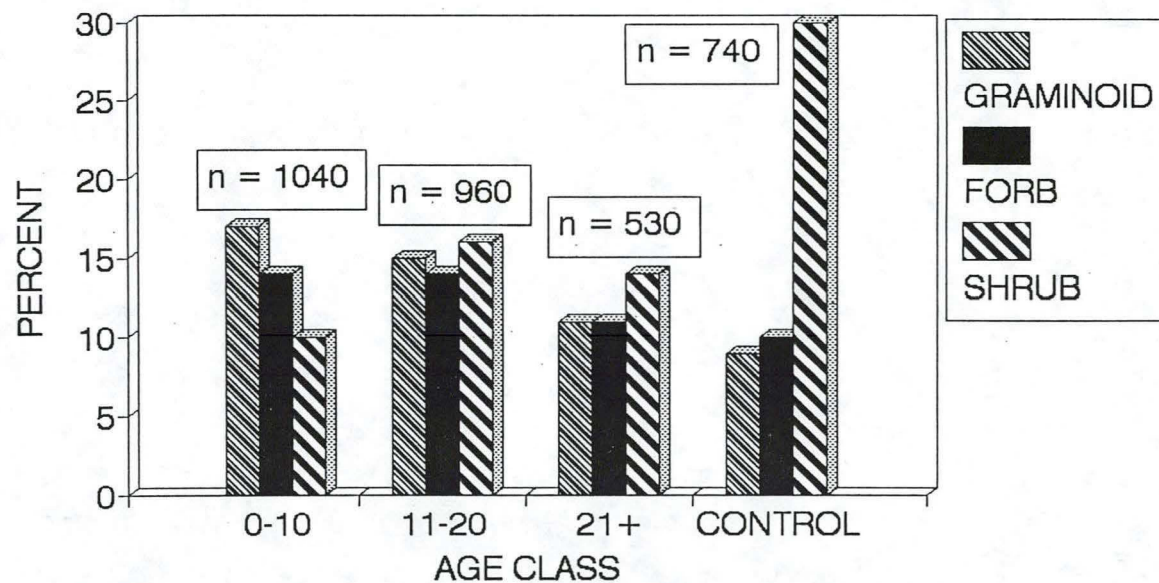


Figure 3. Total estimated canopy cover of vegetative life forms by age class. Canopy cover consists of all plant species. Age classes based on number of years in which scarification took place prior to 1991. The control consists of uncut forest.

96 \pm 4 kg/ha dry weight, being the highest in the 0-10 age class and lowest in the control. This resulted in a rejection of the hypothesis of no difference among age classes. Not all age classes differed significantly ($P > 0.05$). Tukey's Studentized Range Test indicated that the difference between the 0-10 and 11-20 age classes was insignificant ($P < 0.05$). The 21+ and control age classes not only differed significantly from each other but also differed from the remaining clearcut age classes ($P < 0.05$). Dunnett's test against a control indicated that all three clearcut age groups produced significantly more of the selected graminoids than control stands ($P < 0.05$). Mean graminoid production is shown in Figure 4 and Appendix B, Table 8.

Although forb production differed (Figure 5), it was not significant among clearcut age classes or between clearcut age classes and uncut stands for either wet ($P = 0.314$) or dry ($P = 0.326$) weights. Mean weights ranged from 52 \pm 5 kg/ha to 160 \pm 10 kg/ha wet and 12 \pm 1 kg/ha to 60 \pm 10 kg/ha dry. Mean forb production for individual age classes is presented in Appendix B, Table 8.

Grouse whortleberry production ranged from 96 \pm 7 kg/ha to 482 \pm 30 kg/ha wet weight and 40 \pm 3 kg/ha to 194 \pm 12 kg/ha dry weight (Figure 6 and Appendix B, Table 8). Wet weights differed significantly ($P = 0.048$) and dry weights nearly significantly ($P = 0.056$) among clearcut age classes

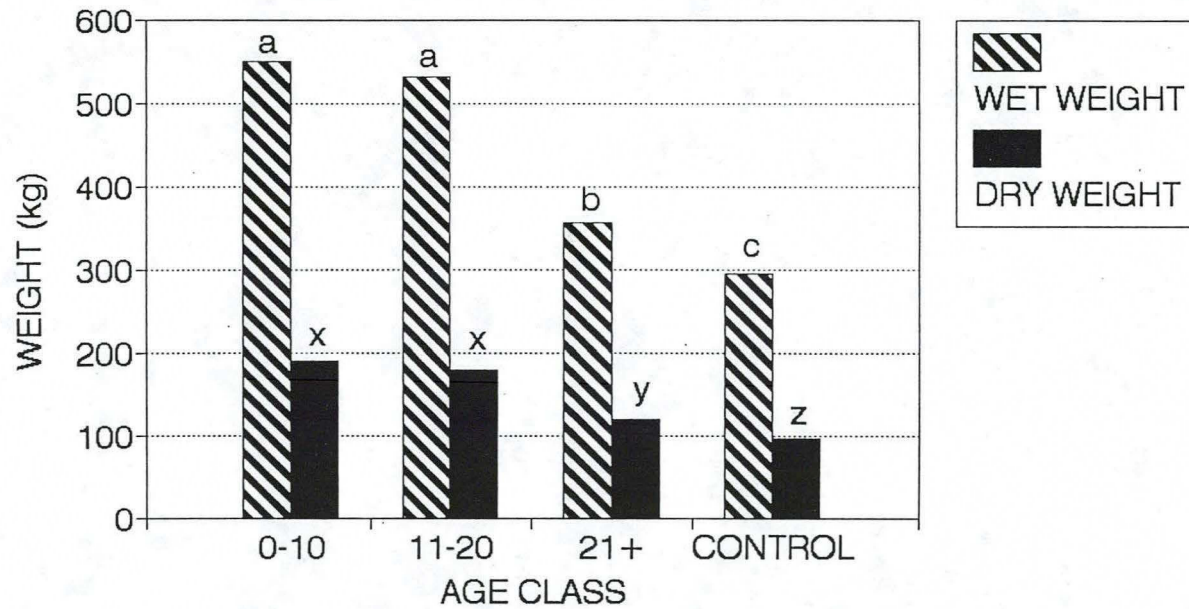


Figure 4. Graminoid production in kg per hectare for wet and dry weights by age class. Age classes based on number of years in which scarification took place prior to 1991. The control consists of uncut forest. Letters (above bars) which differ indicate significant difference.

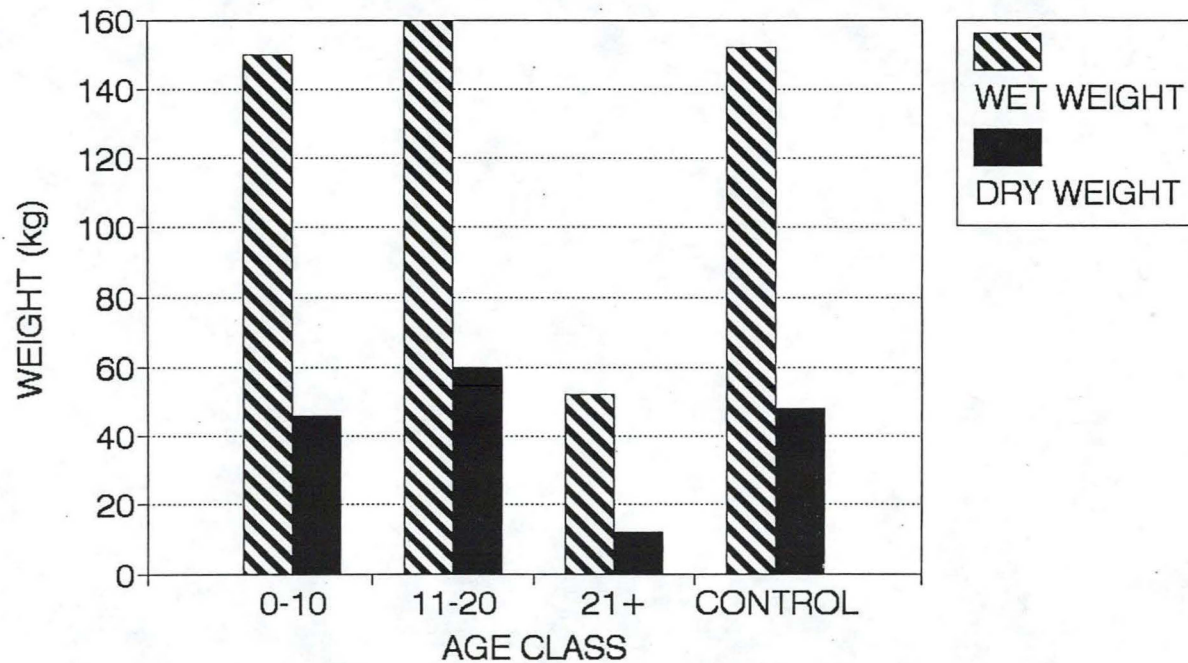


Figure 5. Forb production in kg per hectare for wet and dry weights by age class. Age classes bases on number of years in which scarification took place prior to 1991. The control consists of uncut forest.

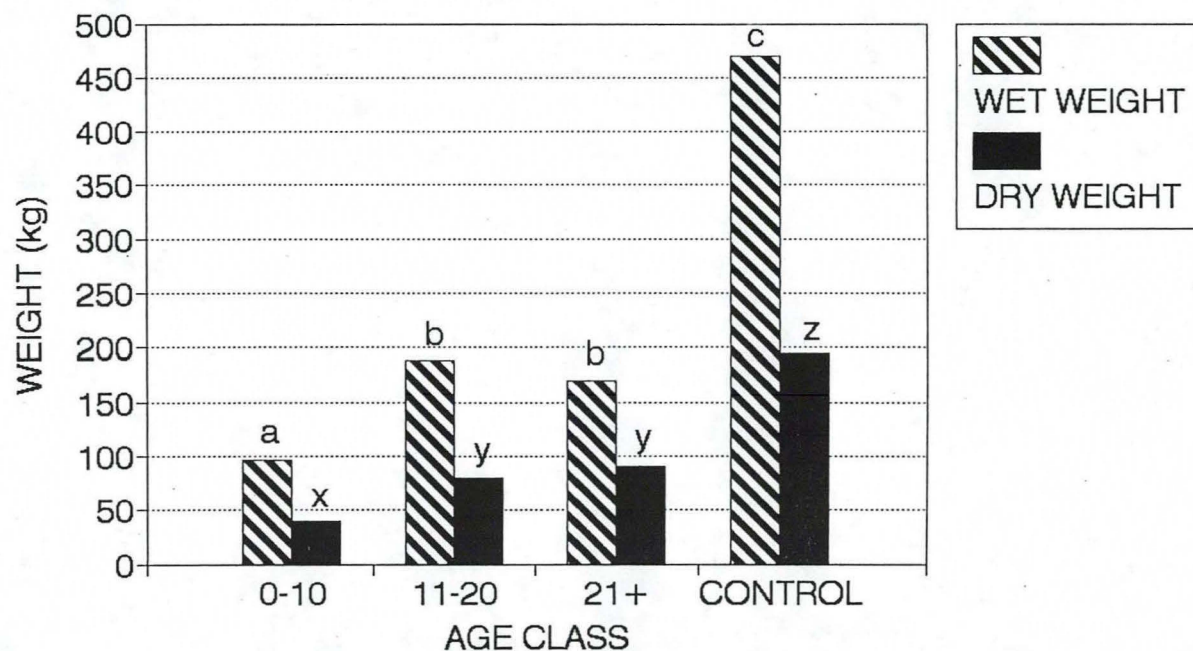


Figure 6. Grouse whortleberry production in kg per hectare for wet and dry weights by age class. Age classes based on number of years in which scarification took place prior to 1991. The control consists of uncut forest. Letters (above bars) which differ indicate significant difference.

and between clearcuts and uncut stands. Tukey's Studentized Range Test indicated that a significant difference existed among all clearcut age classes ($P < 0.05$) with the exception of the 11-20 and the 21+ age classes which did not differ significantly for wet or dry weights ($P > 0.05$). Dunnett's test against a control indicated that all of the clearcut age classes produced significantly less grouse whortleberry than the control for both wet and dry weights ($P < 0.05$).

Canopy coverage determined by the point intercept method differed significantly between age classes for grouse whortleberry ($P = 0.027$). Control stands contained significantly higher canopy coverage than clearcuts ($P < 0.05$, DTAC) (Table 2).

Globe huckleberry wet and dry weights also differed significantly among age classes ($P = 0.0001$ and $P = 0.0005$, respectively). Wet weights ranged from 100 ± 7 kg/ha (0-10 age class) to 482 ± 28 kg/ha (control). Tukey's Studentized Range test indicated that the only age class which differed significantly was the control ($P < 0.05$). Clearcut age classes did not differ significantly ($P > 0.05$). Control stands produced significantly greater wet and dry weights than each of the clearcut age groups ($P < 0.05$, DTAC). Dry weights followed a similar pattern, being lowest (44 ± 3 kg/ha) in the 0-10 age class, increasing to 208 ± 13 kg/ha in the control (Figure 7 and Appendix B, Table 8). Canopy coverage, of globe huckleberry determined from point

Table 2. Average canopy coverage (%) of selected grizzly bear foods as determined for each clearcut age class and the control.

Sample size	0-10 ^a age class 1040	11-20 age class 960	21+ age class 530	Control 740
Species				
GRAMINOIDS				
Agropyron spp.	1	1	1	<1
Bromus spp.	1	<1	<1	<1
Carex spp.	7	7	3	4
C. rubescens	7	8	7	5
F. idahoensis	<1	<1	<1	-
M. spectabilis	<1	<1	<1	-
P. alpinum	<1	<1	<1	<1
Poa spp.	<1	<1	<1	<1
FORBS				
Cirsium spp	<1	<1	<1	<1
C. lanceolata	<1	<1	-	-
E. angustifolium	2	2	1	2
F. virginiana	1	<1	<1	<1
P. gairdneri	<1	-	-	<1
Taraxacum spp.	<1	<1	<1	<1
T. dubius	<1	<1	<1	<1
Trifolium spp.	<1	<1	<1	<1
SHRUBS*				
A. alnifolia	0.1	0.1	-	0.4
S. canadensis	-	0.3	0.8	0.1
V. scoparium	3.7	7.1	5.9	17.7
V. globulare	2.9	4.6	4.4	19.1

a Age classes based on number of years in which scarification took place prior to 1991. The control age class consist of uncut forest.

- Food item not present in age class.

* Shrub canopy coverage determined from point intercepts of transects.

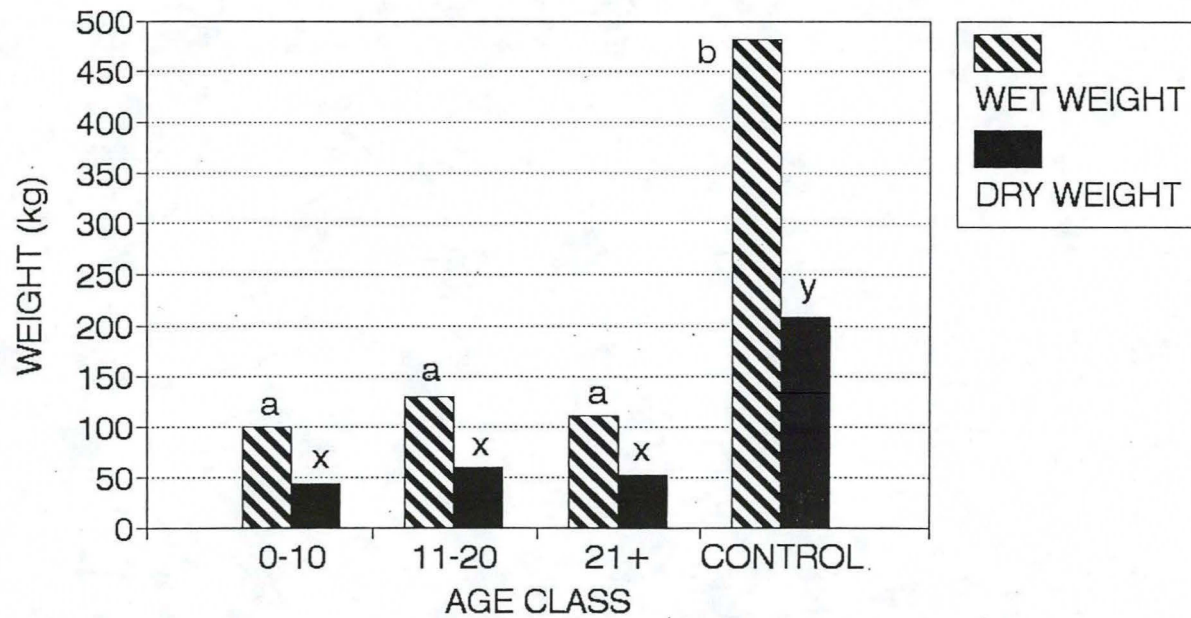


Figure 7. Globe huckleberry production in kg per hectare for wet and dry weights by age class. Age classes based on the number of years in which scarification took place prior to 1991. The control consists of uncut forest. Letters (above bars) which differ indicate significant difference.

intersect of transects, likewise differed among stand types ($P = 0.0001$) and was greater in uncut stands than in clearcuts ($P < 0.05$) (Table 2).

Globe huckleberry plants within uncut stands were found to be significantly taller than their counterparts in clearcuts ($P = 0.0106$). Fifty-seven percent of the plants in uncut stands were 30.5 cm tall or taller as compared to 4.7% in the 0-10, 20.4% in the 11-20, and 23.1% in the 21+ year old clearcuts.

Globe huckleberry production did not differ greatly for individual age classes when scarification by broadcast burning was compared to other forms of scarification. The primary method of scarification was dozer piling (80%, $N=28$). Broadcast burning accounted for 17% ($N=6$) of the scarification methods used on the clearcuts sampled. One 0-10 age class clearcut was broadcast burned while three and two were broadcast burned in the 11-20 and 21+ age classes, respectively. The remaining clearcut was scarified by logging. No statistical test was run due to the small sample of broadcast burned clearcuts, primarily in the 0-10 age class. Mean globe huckleberry weights by age class for broadcast burned clearcuts are compared against the combined dozer piled and lopped clearcuts in Figure 8.

Berry Production

Berry production differed significantly in both numbers of berries ($X^2=65.60$, d.f.=3, $p<0.0001$) and in weight of

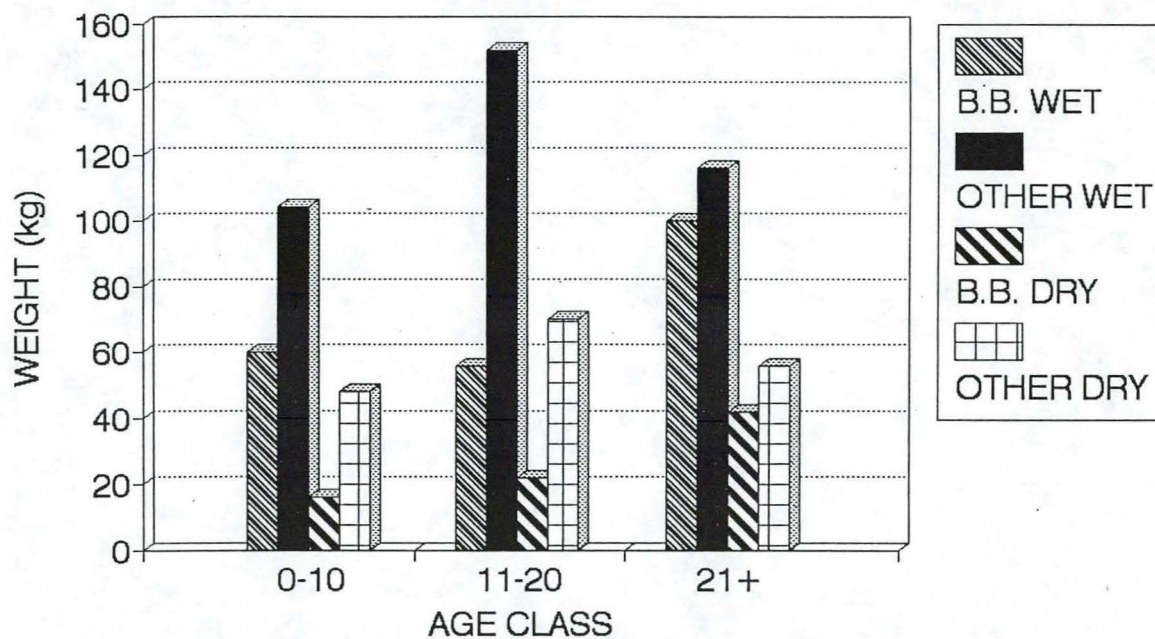


Figure 8. Globe huckleberry production per hectare for clearcuts which were broadcast burned (B.B.) vs other scarification techniques by clearcut age class. Age classes based on the number of years in which scarification took place prior to 1991.

berries ($X^2=29.43$, d.f.=3, $p<0.0001$) for grouse whortleberry. This was also true for globe huckleberry berry production ($X^2=240.43$, d.f.3, $p<0.0001$ for berry numbers and $X^2=66.20$, d.f.=3, $p<0.0001$ for berry weights). Uncut stands produced more berries and greater weights of berries for both grouse whortleberry and globe huckleberry (Figures 9 and 10, and Appendix B, Table 8).

Energy Production

Estimated gross and digestible energy levels determined using dry plant and berry weights for each age class are listed in Tables 3 and 4. Graminoids provided the majority of the gross energy for all clearcut age classes and uncut stands. Forbs comprised nearly all the remaining gross energy in the clearcut age classes with berries providing only a trace. Forbs and berries combined accounted for more than one-third of the gross energy produced in uncut stands. Estimated apparent digestible energy levels followed a trend similar to gross energy levels with graminoids becoming increasingly important in clearcut age classes. Although graminoids still provided the majority (56.4%) of the digestible energy in uncut stands, berries increased in energy production to 27.3%, followed by forbs at 16.3%.

Frequency

Frequency of occurrence differed with grizzly bear food life form and by age class. Graminoids and forbs were found most frequently in the 0-10 age class, occurring in 998 and

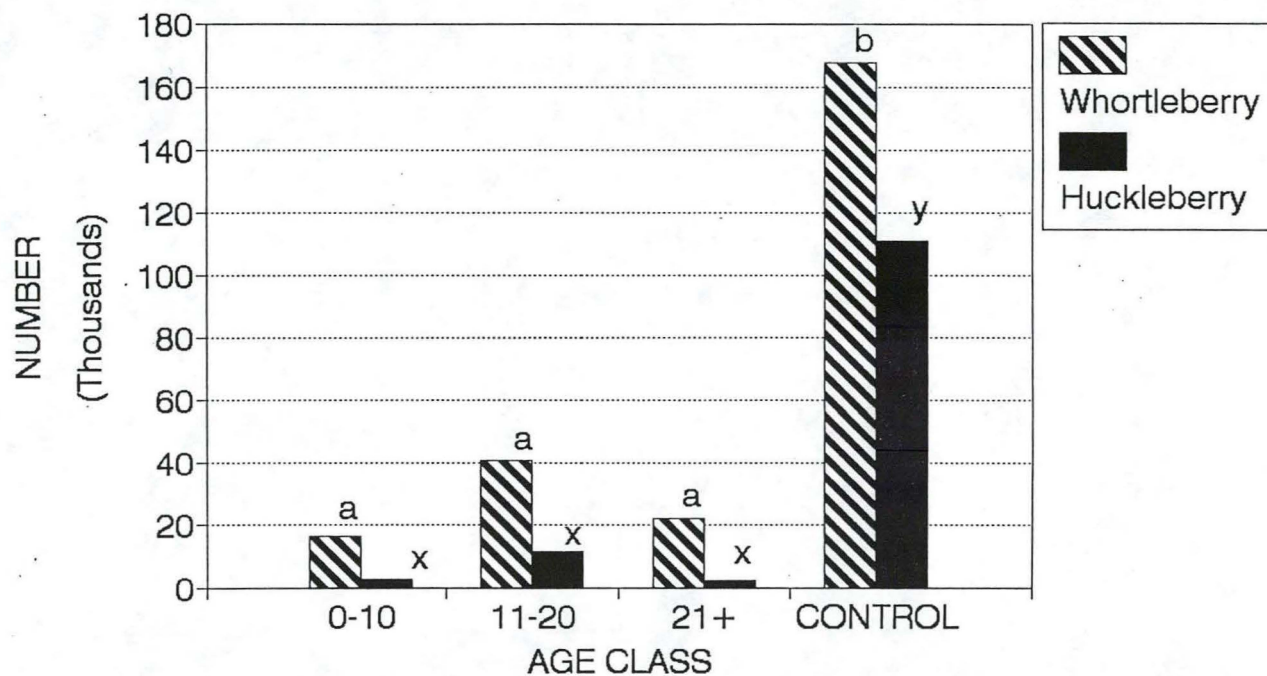


Figure 9. Grouse whortleberry and globe huckleberry berry numbers produced per hectare by age class. Age classes based on number of years in which scarification took place prior to 1991. The control consists of uncut forest. Letters (above bars) which differ indicate significant difference.

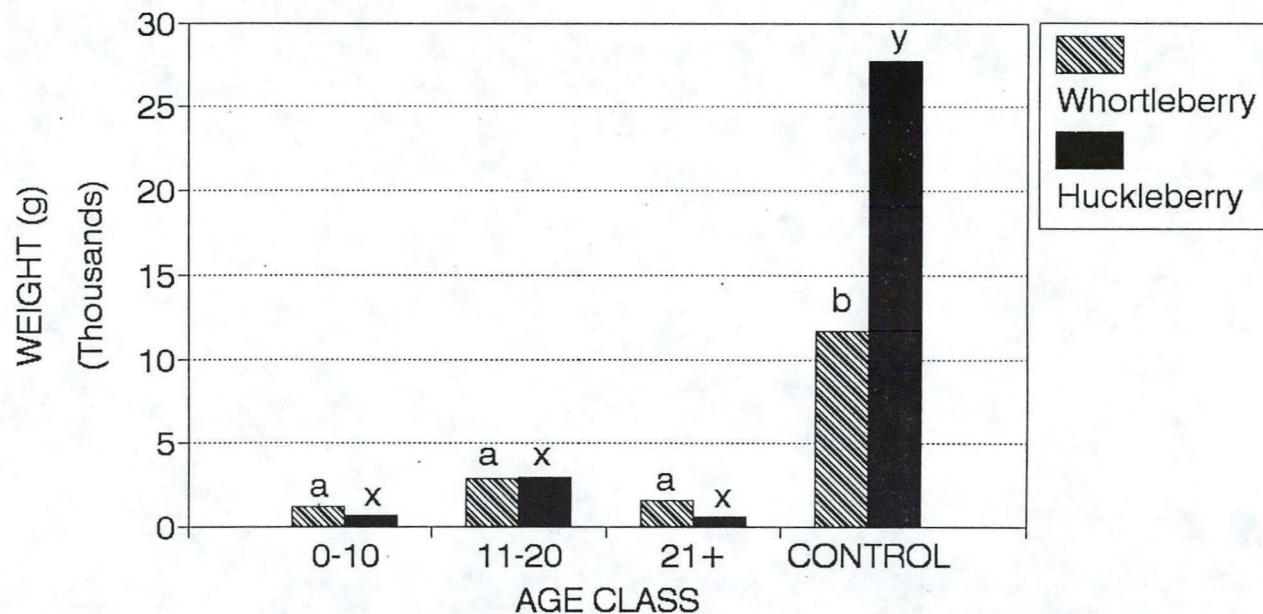


Figure 10. Grouse whortleberry and globe huckleberry berry weights produced per hectare by age class. Age classes based on number of years in which scarification took place prior to 1991. The control consists of uncut forest. Letters (above bars) which differ indicate significant difference.

Table 3. Gross energy (kcal/g) produced per hectare by vegetative life form for individual age classes. Percent composition indicates the percentage each life form contributes to the total gross energy produced. Age classes based on the number of years in which scarification took place prior to 1991. The control consists of uncut forest.

	0-10 Age Class		11-20 Age Class		21+ Age Class		Control Age Class	
Life Form	Gross Energy	% Comp.	Gross Energy	% Comp.	Gross Energy	% Comp.	Gross Energy	% Comp.
Graminoid	6270	82.3	5940	76.9	3960	91.6	3168	65.0
Forb	1334	17.5	1740	22.5	348	8.0	1392	28.5
Whortleberry	9	0.1	23	0.3	12	0.3	94	1.9
Huckleberry	5	<0.1	23	0.3	5	<0.1	222	4.6
Total	7618		7726		4325		4876	

Table 4. Estimated digestable energy (kcal/g). Estimate is energy received per hectare by vegetative life form for individual age classes. Percent composition indicates the percentage each life form contributes to the total energy available. Minimum apparent digestibilities (MAD) were taken from Mealey (1975), Bunnell and Hamilton (1983), and Pritchard and Robbins (1990). Age classes based on the number of years in which scarification took place prior to 1991. The control consists of uncut forest.

	0-10 Age Class		11-20 Age Class		21+ Age Class		Control Age Class	
Life Form	Energy	% Comp.	Energy	% Comp.	Energy	% Comp.	Energy	% Comp.
Graminoid	1216	87.1	1152	81.2	768	92.8	615	56.4
Forb	171	12.2	223	15.7	44	5.3	178	16.3
Whortleberry	6	0.4	22	1.6	12	1.4	88	8.1
Huckleberry	3	0.2	22	1.6	4	0.5	209	19.2
Total	1396		1419		828		1090	

600 of 1040 microplots, respectively. Within control stands, graminoids were present in 632 of the 740 microplots and forbs in 230 of the 740 microplots, resulting in the lowest frequency of all the age classes.

Conversely, grouse whortleberry and globe huckleberry occurred most frequently in uncut stands, occurring in 334 and 410 of the 740 control microplots, respectively. For grouse whortleberry frequency, the control was followed in percent occurrence by the 11-20 age class with 398 of 960 microplots containing grouse whortleberry. The 21+ age class contained grouse whortleberry in 193 of 530 microplots, and the 0-10 age class held grouse whortleberry in 347 of 1040 microplots. Globe huckleberry plants occurred in 344 of 1040 microplots in the 0-10 age class, where as 295 of 960 and 159 of 530 microplots contained globe huckleberry plants in the 11-20 and 21+ age classes, respectively (Figure 11).

Phenology

Phenology of the most frequently found species in each life form was recorded for grizzly bear foods found in each microplot. The most frequently found graminoid, forb, and shrub were Carex spp., fireweed (Epilobium angustifolium), and grouse whortleberry, respectively, which were used in subsequent statistical analysis. There was no significant difference among age classes for Carex spp. ($P = 0.631$), fireweed ($P = 0.474$), or globe huckleberry ($P = 0.193$).

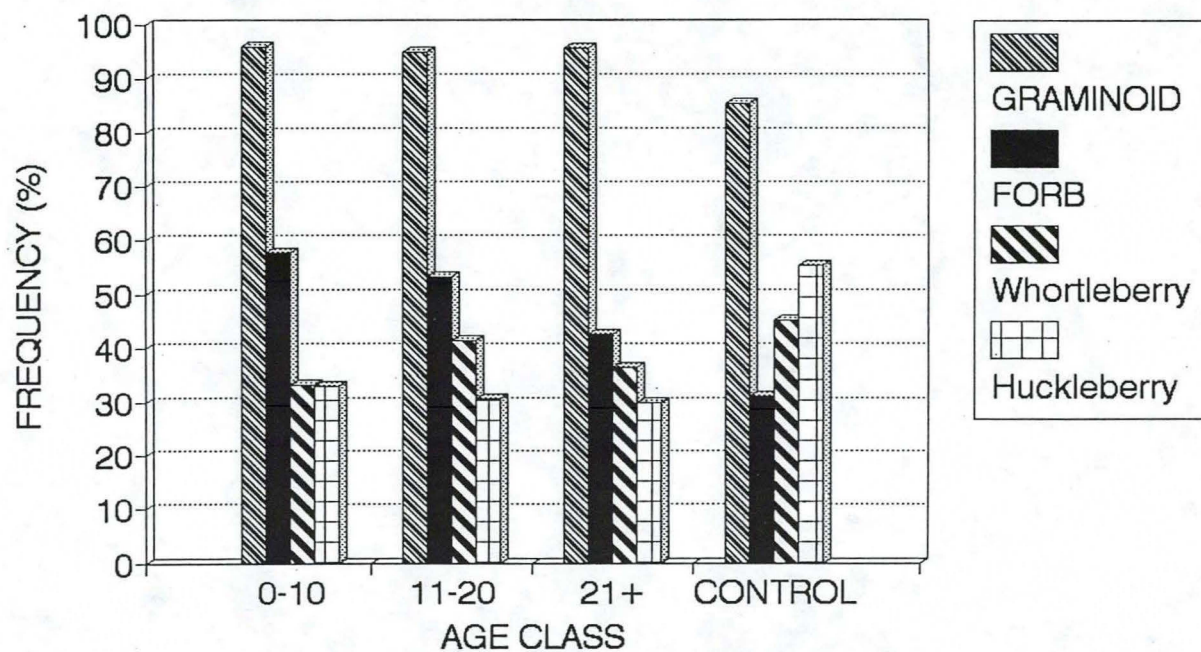


Figure 11. Frequency of occurrence based on presence or absence within individual microplots for vegetative life forms. Age classes based on number of year in which scarification took place prior to 1991. The control consists of uncut forest.

Although not statistically different, the first appearance of the inflorescence stage in Carex spp. occurred approximately two weeks earlier in the control than the clearcut age classes. Epilobium angustafolium reached inflorescence between the second and fourth week in August, occurring first in the 11-20 age class about two weeks ahead of the other age classes. Inflorescence was first observed for globe huckleberry during the first week of June in a control. Globe huckleberry within the clearcut age classes achieved inflorescence approximately one week later. Berries also appeared first in uncut stands, approximately one to two weeks ahead of the clearcuts, with the first development occurring during the first week of August.

Sound Levels

Sound made from an idling pickup truck carried significantly different distances among stand types ($P = 0.0001$). Sound was detected farther from the source in the 0-10 and 11-20 year old age classes than the control ($P < 0.5$ DTAC). Mean distances at which the sound of the idling pickup was maintained above 50 db were approximately 82.8 ± 2.1 m in the 0-10 age class, 71.0 ± 1.8 m in the 11-20 age class, 69.5 ± 1.1 m in the 21+ age class, and 65.2 ± 1.5 in the control. The 21+ age class and the control did not differ significantly ($P > 0.5$).

Bear Sign

One hundred and ten instances of bear use were observed,

consisting of both incidental observations and observations made while conducting bear sign transects. Observed bear activity consisted primarily of disturbed logs (76.4%, $n=84$). Scat and disturbed stumps comprised 12.7% ($n=14$) and 3.6% ($n=4$) of the instances of bear use observed, respectively. Digging sites, claw marks on trees, and dens were combined into an 'other' category which accounted for 2.7% of the bear sign recorded. Five bears were observed during the study comprising the remaining 4.5% of bear use (Figure 12). However, all of the sightings were of black bears. Evidence of grizzly or black bear use could not be differentiated in other instances.

Uncut stands contained the majority of bear sign (53.6%, $n=59$). Clearcuts, clearcut/uncut edges, and select cuts received 33.6% ($n=37$), 3.6% ($n=4$), and 1.8% ($n=2$) of the observed bear use, respectfully. Roads ($N=6$) and hiking trails ($N=2$) combined contained 7.3% of the recorded bear use (Figure 13).

The periphery region (ie. within 30 m of the clearcut edge) accounted for 9 (24%) of the observed sign within clearcuts. Seventy-five percent ($n=28$) of the observed bear sign was within 100 m of an edge.

Tree canopy cover over 30% accounted for 78% of the observations in clearcuts. Individual age classes contained 13.5% ($n=5$), 54.0% ($n=20$), and 32% ($n=12$) within the 0-10, 11-20, and 21+ age classes.

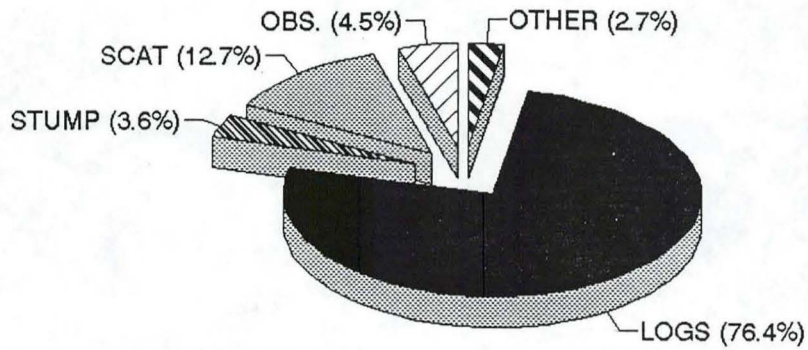


Figure 12. Percentage of bear sign observed by activity type. Claw markings, dens, and digging sites make up the other category.

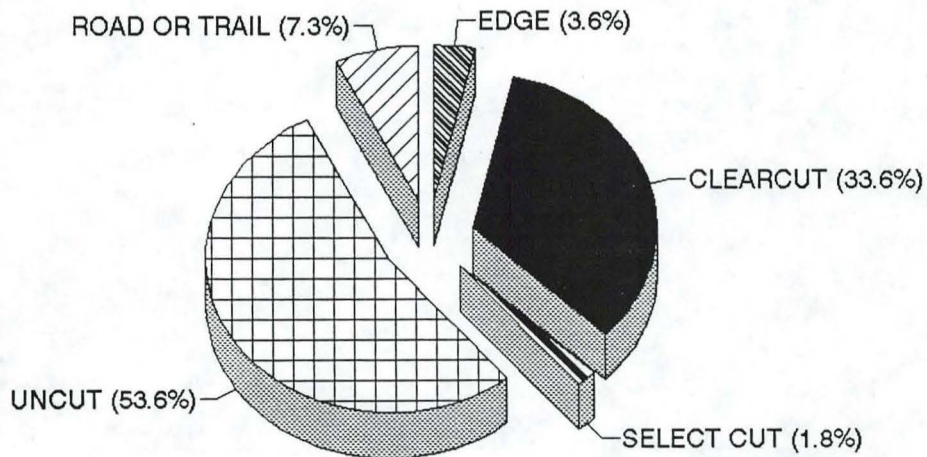


Figure 13. Percentage of bear sign observed by area type. Edge areas consist of the border between clearcuts and uncut stands.

DISCUSSION

Food Production

Literature concerning vegetative recovery of clearcuts generally indicates an initial increase of graminoid and forb life forms and a decline of shrubs. As tree cover increases, graminoid and forb densities decrease and shrubs increase. This is then followed by a decline in all ground vegetation as tree canopy cover increases (Leege and Hickey 1971, Dyrness 1973, Schmidt 1979). A similar pattern was found for graminoid and forbs within clearcuts in the study area. Graminoid and forb canopy cover was greatest on recent clearcuts and declined with succession of the harvested stands. Total shrub canopy cover generally increases for the first 20 years. A slight decline was noted in the 21+ year old clearcuts. However, total shrub cover was greatest in the uncut stands which also contained the highest tree canopy coverage.

When those species utilized by grizzly bears were considered, graminoid production and frequency was consistent with literature, decreasing with stand age. Forb production increased following clearcutting until age 21+ where it then declined sharply. Uncut stands and clearcuts less than 20 years old produced nearly equal weights of forbs. Forb frequency, however, declined with clearcut age and was lowest in uncut stands. When frequency of occurrence is compared to wet and dry weights, forb

frequency is not consistent with the overall weight of plants produced. Individual plants within uncut stands were heavier than their counterparts in clearcuts. This may be an indicator of increased succulence. Graham (1978) found that moisture content of grass under forest canopy was higher than that of exposed sites during the fall. This may also be true of forbs, however, more research is needed to determine if the same correlations exist.

Vaccinium spp. production and frequency was greatly reduced with clearcutting. Scarification of the site may account for much of the reduction (Schmidt 1979, Zager 1980, Martin 1983, Zager et al., 1983) as Vaccinium spp. reproduce primarily by rhizomes (Stark 1987).

In northwestern Montana, globe huckleberries serve as a concentrated major food source (Martin 1983). Huckleberry shrub canopy cover in northwestern Montana was considered to be moderate to high if percent cover ranged from 25% to 45% (Martin 1983). I recorded an average of 19% for uncut stands which contained the most productive sites. Waller (1992) found that total mean shrub canopy cover ranged from 78.8% to 84.9% on clearcuts. Total shrub canopy within clearcuts on my study area ranged from 6.7% to 12.1%. This indicates that shrubs, including globe huckleberry, comprise considerably less canopy cover in the subalpine fir/globe huckleberry habitat type of Northwestern Yellowstone ecosystem than was reported for habitat types in

northwestern Montana. Martin (1983) and Zager (1980) indicated that harvested stands produce the most huckleberries 8 to 15 years after harvest. However, in the northwestern and western Yellowstone Ecosystem, the two primary shrubs grouse whortleberry and globe huckleberry were reduced significantly when clearcutting and scarification took place. Globe huckleberry production did not differ among clearcut age classes and may have declined in frequency as clearcut age increased.

A partial explanation for the differences in globe huckleberry production and recovery found in the two ecosystems may be due to precipitation. Average yearly precipitation on Waller's (1992) study area in northwestern Montana ranged from approximately 76 cm to 203 cm with the majority lying in the 102 cm to 152 cm range (USDA 1981). The majority of my study area receives from 76 cm to 127 cm of precipitation annually with most of my study sites obtaining less than about 114 cm per year.

Temperature extremes may also be an important factor in globe huckleberry production and recovery in clearcuts within the western and northwestern Yellowstone ecosystem. The apparent reduction in Vaccinium spp. frequency of occurrence as clearcut age increased may partially be due to the occurrence of frost after greenup had been initiated. Minore and Smart (1978) noted that huckleberry leaders are intolerant to temperatures below -6C. Therefore,

recurring frost damage over many years may result in the loss of new leaders and eventually death of Vaccinium plants in clearcuts, thus reducing plant frequency.

If the time when snow-water equivalents reach zero (when snow pack melts) indicates initiation of greenup, then several occurrences of frost were noted on the study site after the growing season had started. Since snow cover on clearcuts generally melts sooner than in uncut stands, plants in clearcuts may be subjected to cold temperatures when plants in uncut stands are still insulated by snow.

The occurrence of frost induced mortality may also be supported by general observations of an association between huckleberry plants and cover such as logs, stumps, and rocks within clearcuts. Many of these objects were remnants of scarification efforts as the soil appeared to be disturbed. Globe huckleberry plants associated with remaining slash appeared brown and damaged above the point where the slash offered protection.

Globe huckleberry shrub height is generally correlated to tree canopy density (Martin 1983) and berry production is associated with heavier plants (Stark 1987). The majority of globe huckleberry plants within clearcuts was less than 30.5 cm tall. Younger plants and frost may contribute to the smaller size of plants within clearcuts. If wind, melting, or other environmental conditions cause snow depths to drop, the shoots of globe huckleberry plants could be

damaged. This in combination with frost occurrence after snowmelt may hold the size of plants below that of maximum berry production.

Flower and berry production can also be reduced by frost via flower damage, freezing of young berries, and reduction of pollinators (Martin 1983, Stark 1987). Temperatures fell below freezing on several occasions in May and early June during the 1993 field season, which may explain the relative lack of berry production observed.

Energy production

On average, clearcuts less than twenty years old produce more gross energy and more digestible energy in food plants than other stands. However, this energy is primarily in the form of graminoids, a low quality forage for bears (Bunnell and Hamilton 1983, Pritchard and Robbins 1990). The gross and digestible energies produced by forbs and Vaccinium berries, which are generally of higher quality, were estimated to be much higher (6.8 times) in uncut stands than in clearcuts.

The estimated energy production did not account for changes in energy content and digestibility due to phenology. The estimated digestible energy for graminoids is highest during spring and declines as phenology progresses (Mealey 1975, Graham 1978). The gross energy and digestible energy estimates also do not allow for differences in moisture, protein, or mineral content in

exposed vegetation and vegetation under tree canopy cover. Graham (1978) reported that moisture, protein, and mineral levels tended to be higher in grasses beneath forest canopy than on exposed sites. The same may likely be true for other vegetative forms. Obviously a bear cannot or will not utilize all sources of energy available. During late summer and fall when grizzly bears tend to increase feeding activity to accumulate fat reserves for winter hibernation, a concentrated source of calories becomes increasingly important (Craighead and Mitchell 1982). Graminoids, generally, do not offer such a source (Bunnell and Hamilton 1983, Pritchard and Robbins, 1990).

The gross and digestible energy estimates used in this study are deficient in describing the impact of insects and gophers on both gross and digestible energy levels. These estimates were not included due to the difficulty of determining actual weights produced.

Insect use, in this case primarily ants, cannot be overlooked as an important aspect in grizzly bear diets. Mattson et al. (1990) reported insects in 7.7% of scat volume during a ten year period from 1977-1987. Picton et al. (1985) found ant use to increase during drought conditions. In more mesic years bears continue to use ants with use being highest during summer and early fall (Picton et al. 1985, Mattson et al. 1990). Although actual insect production was not measured in this study, the greater

number of downed logs in the uncut stands suggests higher insect production. If insect production is greater in uncut stands, energy production in uncut stands could be increased greatly compared to clearcuts. Because grizzly bear diets vary considerably from year to year, the actual amount of energy available depends on food selection for that particular year. The greater number of non-graminoid foods within uncut stands may provide foraging opportunities not available at any appreciable level in clearcuts.

Sound Levels

Several studies have shown that grizzly bears are displaced from areas of high human activity (Mace and Jonkel 1980, Zager 1980, Archibald et al. 1987, McLellan and Shackleton 1989). Increased human activity is often accompanied by a rise in human-induced sound levels within the area. Human-caused noises alone may result in displacement of grizzly bears. The presence of vegetation can reduce sound transmission. Aylor (1972) reported that foliage reduces sound transmission substantially, especially at higher frequencies, by enhancing scattering. Reducing tree cover by clearcutting significantly impacted the distances sound traveled. If the ability to detect human sounds influences use, grizzly bear avoidance of clearcuts may not be limited to the cut-over area. Aylor (1972) found that sound is attenuated less as distance from the sound source increases. Therefore, attenuation by vegetation

around clearcuts will be less effective at reducing sounds produced within the clearcut. This may increase the distance of grizzly bear displacement from the noise source.

Bear Use

Although the majority of bear use observed in this study is believed to be caused by black bears, regardless of species, the results of this study support those found by Lindzey and Meslow (1977), Zager 1980, Young and Beecham (1986) and Unsworth et al. (1989). The higher use found in uncut stands can be attributed to log use, which comprised the majority (76%) of observations. Higher log use in uncut areas was likely related to availability. Generally, there were more logs present in uncut stands due to cleanup of clearcuts. However, if availability is considered, bears used logs in clearcuts at nearly the same rate as logs in uncut stands. Clearcuts accounted for one-half as many disturbed logs as uncut stands. Clearcuts also contained one-half as many logs as uncut areas on average. The majority of log use in uncut stands consisted of partial use of the log, which was generally an entire tree. Logs within clearcuts were generally small remnants of logging activity but bears were able to utilize insects within and under the logs. A black bear was observed feeding in a clearcut in which it would roll over the logs with relative ease. Insects in logs in uncut stands may require more energy to obtain as the bear generally had to tear a portion of the

log apart to get access to the insects. The amount of energy gained by utilizing logs in clearcuts rather than those in uncut areas is speculative. However, if less energy is required, clearcuts may provide an efficient means of feeding for bears utilizing insects. More research is needed to determine the importance of these insects to bear diets and energetics.

No incidence of gopher-cache use by digging sites was observed. The only two instances of digging sites appeared to be associated with insect or plant use as no gopher mounds were observed in the area. Both of these digging sites occurred in 11-20 age class clearcuts and were within 20 m of the edge. The lack of digging sites for gopher caches may be due to the general absence of gophers in uncut stands and a lack of corm or tuber producing plants in clearcuts where gophers were more numerous.

MANAGEMENT IMPLICATIONS

Studies within portions the Northern Continental Divide Ecosystem (NCDE) generally indicate that logging tends to increase the amounts and kinds of bear foods within the harvested area (Zager 1980, Martin 1983). Management decisions made from these findings may not apply to the Yellowstone ecosystem (Mattson and Knight 1991 and this study). Climatic conditions and soil productivity within the Yellowstone ecosystem differ significantly from the NCDE which is more mesic, has fewer temperature extremes, and is generally more productive (Mattson and Knight 1991). The results of this study support the statements made by Mattson and Knight (1991). However, previous studies have not dealt with the effects of logging on bear foods in the Yellowstone ecosystem. Thus, managers have had to make decisions based on the best NCDE information.

Globe huckleberries are a major food source in much of the NCDE. The relative lack of huckleberries and other consistent high quality foods within the Yellowstone ecosystem may be limiting to the grizzly bear population (Mattson et al. 1991). Results of this study indicate a negative association between logging and globe huckleberry recovery. Reduction of globe huckleberry through clearcutting may further limit grizzly bear densities.

Graminoids were the only forage to increase after clearcutting. Graminoids also contributed nearly all the

estimated energy produced in clearcut stands. Due to the low quality and general availability of graminoids, clearcuts harvested since 1965 appear to be lost as quality foraging sites for grizzly bears, and may remain that way for several decades. Many stands may never return to their uncut status.

Other methods of timber management, such as select cuts which do not remove the entire canopy cover or require heavy scarification, should be considered. Unsworth (1984) noted a wide variety of bear foods in select cuts in west-central Idaho. However, logging practices, whether select cuts or other methods, which maintain or increase grizzly bear foods within the Yellowstone ecosystem are needed. Determining the appropriate timber management scheme may require experimentation and research. Road creation should be kept to a minimum to reduce human disturbance and possible increased mortality (Johnson 1977, Archibald 1983, McLellan 1990).

As the potential for grizzly bears to expand their range is being reduced by increased human intrusion the remaining areas become more important to continued population viability. Further loss of habitat through clearcutting could have negative impacts on grizzly bear populations, which could last for at least 25 years. Loss of quality forage, reduction in forage variety, increased human disturbance due to greater access, and the increased sound

transmission associated with greater human access are negative impacts that may limit grizzly bear use of clearcuts and their surrounding area. Although not statistically significant, the results of this study indicate that all bear use, including black bears, may be reduced in clearcuts within the western and northwestern Yellowstone ecosystem.

If grizzly bears avoid clearcuts as literature suggests (Lindzey and Meslow 1977, Zager 1980, Waller 1992), clearcuts may be used in a positive way by reducing human-bear encounters in and around populated areas. This may be of particular value within the Yellowstone ecosystem due to the apparent decline of preferred bear foods as a result of clearcutting. However, in areas where grizzly bear foods are abundant, particularly if bears are known to frequent the area, an increase in mortality may result (Johnson 1977, Archibald 1983, Brody and Stone 1987). Although the Yellowstone grizzly bear population appears to be increasing at a rate of approximately 4.6% per year (Eberhardt et al. 1994), increased mortality due to human encounters could become limiting, particularly if those mortalities are females (Knight and Eberhardt 1986).

It is up to the manager to determine the importance of an area before making decisions as to the type of timber management to implement. Clearcuts do not appear to be a viable option in much of the Yellowstone ecosystem if the

grizzly bear is included in management decisions. In the Yellowstone area, in general, and in globe huckleberry habitat types in particular, not harvesting trees should remain one of the timber-management considerations, at least until timber-harvesting methods that conserve grizzly bears and their food base have been developed.

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APPENDICES

APPENDIX A
DESCRIPTION OF VARIABLES AND
SPECIES LIST

Table 5. Plot and transect variables measured in data collection. Variables are primarily derived from USFS Ecosystem Classification Handbook FSH 12/87 R-1 Suppl.

STAND INFORMATION

- 1) DATE - ENTERED AS mm/dd/yy.
- 2) STAND I.D. - Stand identification number used by the Forest Service.
- 3) STAND TYPE - Entered as either a clearcut or a control.
- 4) STAND AGE - Recorded as date of last major scarification.
- 5) STAND SIZE - Determined from Forest Service data. Entered in acres and later converted to hectares.
- 6) COVER TYPE - Derived from Despain (1986).
- 7) SCARIFICATION TYPE - Preparation method use to prepare site for planting, seeding, or natural regeneration. Determined from Forest Service data.
- 8) ASPECT - General aspect of the entire stand coded as follows:

<u>Direction</u>	<u>Degrees</u>
N	337.5 - 22.5
NE	22.5 - 67.5
E	67.5 - 112.5
SE	112.5 - 157.5
S	157.5 - 202.5
SW	202.5 - 247.5
W	247.5 - 292.5
NW	292.5 - 337.5

- 9) SLOPE - Determined by use of an clinometer at the transect level and averaged for overall slope of stand.
- 10) SLOPE SHAPE - Topographical shape of the overall stand. recorded as follows:

<u>Code</u>	<u>Slope Shape</u>
1	Even or straight
2	Convex or rounded
3	Concave or depressed
4	Patterned
5	Undulating pattern of low relief ridges or knolls and draws.
- 11) ELEVATION - Determined using an altimeter and topographic maps.

Table 5. Continued.

- 12) TOPOGRAPHIC CHANGE - Distance in meters from the center of the clearcut to the nearest road, meadow, and stream. Estimated by observer from topographic maps.
 - 13) TREE CANOPY COVER - Estimated percent tree canopy recorded at the start and end of every transect.
 - 14) BASAL AREA - Measured at start and end of every transect with a cruise-all.
 - 15) SHRUB COVER - Measurement of shrub cover which fell directly below the transect.
 - 16) TRANSECT VARIABLES - Count of the number of trees (by size class), logs, stumps, ant hills, and gopher mounds within a 1 m strip along all transects.
-

Table 6. Species list of selected grizzly bear foods. Species listed were common grizzly bear foods observed in fecal analysis reported by Mattson et al. (1990).

GRAMINOIDS

Species	Code	Species	Code
¹ <u>Agropyron canium</u>	AGCA	² <u>Caru rubescens</u>	CARU
¹ <u>Bromus anomalous</u>	BRAN	<u>Festuca idahoensis</u>	FEID
¹ <u>Bromus carinatus</u>	BRCA	<u>Melica spectabilis</u>	MESP
¹ <u>Carex raynoldsii</u>	CARA	<u>Phleum alpinum</u>	PHAL
¹ <u>Carex praticola</u>	CAPR	² <u>Poa spp.</u>	POA

FORBS

Species	Code	Species	Code
¹ <u>Cirsium scariosum</u>	CISC	³ <u>Osmorhiza spp.</u>	OSMO
¹ <u>Cirsium foliosum</u>	CISC	<u>Perideridia gairdneri</u>	PEGA
<u>Claytonia lanceolata</u>	CLLA	³ <u>Potamogeton spp.</u>	POTA
<u>Equisetum arvense</u>	EQAR	<u>Taraxacum spp.</u>	TARA
<u>Epilobium angustifolium</u>	EPAN	<u>Tragopogon dubius</u>	TRDU
<u>Fragaria virginiana</u>	FRVI	<u>Trifolium spp.</u>	TRIF
³ <u>Lomatium spp.</u>	LOMA		

SHRUBS

Species	Code	Species	Code
<u>Amelanchier alnifolia</u>	AMAL	<u>Vaccinium globulare</u>	VAGL
<u>Shepherdia canadensis</u>	SHCA	<u>Vaccinium scoparium</u>	VASC

¹ Species of similar genus were included and all species of similar genus recorded under: genus name.

² Not listed in Mattson et al. (1990) but included on list (Picton personal comm.)

³ Not present in sampled stands.

APPENDIX B
TABULATED RESULTS

Table 7. Correlation coefficients of vegetative life forms for wet and dry weights as determined from clipped plots.

<u>Life Form</u>	<u>Wet (r^2)</u>	<u>Dry (r^2)</u>	<u>Sample Size (N)</u>
Graminoid	0.939	0.899	65
Forb	0.897	0.935	37
Shrub	0.937	0.925	44

Table 8. Mean wet and dry weights and standard errors in kg per hectare for vegetative life forms. Age classes represent the number of years in which scarification took place prior to 1991. The control consists of uncut forest.

	0-10		11-20		21+		Control	
	Age Class		Age Class		Age Class		Age Class	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Sample size	1040	1040	960	960	530	530	740	740
Life form								
Graminoid	550+/-15	190+/-7	532+/-14	180+/-5	356+/-15	120+/-5	294+/-11	96+/-4
Forb	150+/-5	49+/-3	160+/-10	60+/-4	52+/-5	12+/-1	152+/-18	48+/-6
G. Whortleberr	96+/-7	40+/-3	188+/-12	80+/-5	170+/-15	90+/-11	470+/-30	194+/-12
G. Huckleberry	100+/-7	44+/-3	130+/-10	60+/-5	112+/-11	52+/-5	482+/-28	208+/-13
Whortleberries	1.1+/-0.1	0.2+/-0.02	2.9+/-0.2	0.6+/-0.04	1.6+/-0.2	0.3+/-0.04	11.7+/-0.5	2.3+/-0.1
Huckleberries	0.7+/-0.04	0.1+/-0.01	2.9+/-0.05	0.6+/-0.01	0.6+/-0.1	0.1+/-0.2	27.7+/-0.6	5.5+/-0.1

APPENDIX C
STATISTICAL MODELS

Table 9. Models used in analysis of variance for variables collected during study. Type refers to the age class assigned each clearcut and control plot sampled, stand refers to the individual stands, location is the position within each clearcut (ie. interior or periphery), transect is the individual transect number, and point is the individual location where a noise level measurement was taken. The u and E represent the grand mean and random error, respectfully.

<u>Variable</u>	<u>Model</u>
Plant weights (wet and dry)	$^aY = u + \text{Type} + \text{Stand}(\text{Type}) + \text{Location}(\text{Stand} * \text{Type}) + \text{Transect}(\text{Location} * \text{Stand} * \text{Type}) + E$
Transect level variables	$^{ab}Y = u + \text{Type} + \text{Stand}(\text{Type}) + \text{location}(\text{Stand} * \text{Type}) + E$
Plot level variables	$^cY = u + \text{Type} + ^d\text{Stand} + E$
Interior and periphery plant weights	$Y = u + \text{Location} + \text{Stand} + ^e[\text{Location} * \text{Stand}] + \text{Transect}(\text{Location} * \text{Stand}) + E$
Noise levels	$Y = u + \text{Type} + \text{Measurement}(\text{Type}) + ^d\text{Stand} + E$
Berry numbers and weights	$Y = u + \text{Type} + E$ [nonparametric]

^a Stand(Type), Location(Stand*Type), Transect(Location*Stand*Type) are considered to be random. Parenthesis and * indicate nesting.

^b Transect level variables include basal area, tree numbers and canopy cover, VASC and VAGL canopy cover, as well as log, stump, and gopher mound numbers.

^c Plot level variables include elevation, slope, aspect, and slope shape.

^d Used as a covariate.

^e Interaction effects of a factorial design represented by [].